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COMMERCIAL PLANTING ON REDWOOD CUT-OVER LANDS

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AN UNUSUAL PLANTING PROJECT

Between 1922 and 1932, a redwood planting project was undertaken by private interests in California that received an unusual amount of publicity both because of the size and character of the undertaking and because of the wide interest in the redwood region itself. Under the direction of a firm of forest engineers, the principal redwood lumber companies of Humboldt and Mendocino Counties undertook to improve the productivity of their cut-over lands by planting currently all newly logged areas and, as rapidly as practicable, all poorly stocked areas already logged. During the period covered by the project, 10 companies cooperated in the planting of 12,700,000 trees on 26,400 acres at a cost of approximately $234,000.

Although some of the operators engaged in this planting as part of a plan to develop a sustained-yield operation—or, in other words, to put their forest lands on a basis of continuous productivity—other considerations had much weight. One persuasive influence was the growing public interest in conservation in the redwood region. As the majesty of the virgin redwood stands, the impressive size, age, and vitality of the individual trees, and the unexcelled growth capacity of the better sites became more widely recognized,

[1] Maintained in cooperation with the University of California, at Berkeley, Calif.

many people came to realize that these stands constitute not only an invaluable asset, but a serious responsibility, and gradually the welfare of this forest of the northern California coastal section became a matter of national and even world-wide concern.

Another consideration which spurred on the interest in forestry in this section was the dawning realization that, sooner or later, timber production would have to replace timber mining if the industry was to be maintained.

Furthermore, because of the unexcelled growth capacity of the better redwood sites, capable of producing from 1,000 to 2,000 board feet per acre per year, the proposal to place the redwood industry on a self-perpetuating basis was well within the range of commercial practicability. The advantages of such a program to the operators included the protection of manufacturing plants, railroads, and other investments which would soon become valueless unless sustained yield were put into effect; it made possible also the recovery of timber values that could not be realized during the first cut.

Thus, as a result of public interest in the redwood region, the growing demand for a forest policy that would insure the productivity of our remaining forest lands, and the promise of a permanently established industry, several of the redwood operating companies combined to put into operation a widespread planting project. The management plan,[2] prepared by the forest engineers retained, called for the continuation of the general practice of clear cutting, to be followed by a planting program that would involve the reforestation not only of all newly logged areas immediately after logging, but also, as rapidly as possible, the older cut-over areas that were poorly stocked. The ambitious nature of this undertaking is indicated by the fact that the companies involved normally log approximately 8,000 acres of timberland annually and in 1922 their combined holdings of old, poorly stocked cut-over areas were roughly 250,000 acres. To keep the newly logged areas planted currently and to reforest satisfactorily the old cut-over areas within 20 years would have necessitated the planting of more than 20,000 acres annually. As a matter of fact, nothing like so large an operation was even attempted.

On the completion of reports on the holdings of each of the companies interested, five of the principal operating companies of Humboldt County formed in 1922 the Humboldt County Reforestation Association to handle the project in their county. At the same time the Redwood Fire and Protective Association of Mendocino County was organized for the same purpose by five operators of Mendocino County. Foresters were then employed by each of the associations and by several of the companies individually.

The Pacific Lumber Co. agreed to supply stock for the five Humboldt County companies and established a forest nursery for this purpose at Scotia on a redwood stump-land flat in the fall of 1922. During the first planting season of 1922–23, only one-sixth of an acre was developed, but this was enlarged to 6 acres with 54,000 square feet of seedbed area by 1927. The yearly output was increased from 42,000 seedlings in 1923 to 2,245,000 seedlings and transplants in 1927;

[2] MASON, D. T. CALIFORNIA REDWOOD. 77 pp. Rev. May 1, 1922. [Mimeographed Circ.]

but by 1931, the last year of field planting, it had been reduced to 465,000.

In Mendocino County, the Union Lumber Co. contracted to supply the planting stock from its forest nursery, established in 1921 near Fort Bragg in cooperation with the forestry school of the University of California. The original 4 acres was enlarged to 8 in 1925 and to 9 in 1927. The output of seedlings and transplants increased from 300,000 in 1923 to 1,528,900 in 1926, but fell off to a negligible number in 1931. The Caspar Lumber Co. maintained a small nursery, about one-third of an acre, from 1923 to 1927. This nursery produced only 62,700 seedlings and transplants in its peak year, 1925, and its total output was probably less than 200,000.

Field planting was begun in both counties in the winter of 1923–24 with 342,000 trees of 1–0 [3] and 1–1 stock, most of which were planted in Mendocino County. In the last planting in the spring of 1931, the 465,000 trees set out were mostly 1–0 redwood. The extent of the participation by the 10 different companies is shown in table 1, which indicates also that nearly half of the entire planting was done by two companies, Pacific and Union, and that two of the other companies, Dolbeer-Carson and Glen Blair, contributed only a very small part of the total.

TABLE 1.—*Acreage and number of trees commercially planted in Humboldt and Mendocino Counties, 1923–31*

County and lumber company	Area planted	Trees planted	Average planting per acre
Humboldt:	*Acres*	*Number*	*Number*
Pacific	[1] 5,814	3,493,990	601
Little River Redwood	3,299	1,285,010	390
Hammond	2,825	1,120,600	397
Northern Redwood	2,000	763,000	382
Dolbeer-Carson	400	150,000	375
Total	14,338	6,812,600	475
Mendocino:			
Union	5,150	2,551,000	495
Mendocino	1,666	797,000	478
Glen Blair	100	47,000	470
Caspar	3,325	1,587,970	478
Albion	1,844	920,000	499
Total	12,085	5,902,970	488
Aggregate	26,423	12,715,570	481

[1] 297 acres of this area was planted twice.

The annual output of trees from the Scotia nursery in Humboldt County from 1923 to 1931 was as follows:

1923–24	41,960	1928–29	1,025,280
1924–25	677,250	1929–30	269,800
1925–26	971,950	1930–31	465,000
1926–27	2,244,750		
1927–28	1,122,100	Total	6,818,090

[3] In describing planting stock by such a symbol as "1–0" or "1–1", the first number refers to the number of years that the plant remained in the original seedbed and the second to the number of years in the transplant bed. 1–0 stock, therefore, designates 1-year-old seedlings that were not transplanted. 1–1 is stock left 1 year in the seedbed, then transplanted and left 1 year in the transplant bed.

Complete records for Mendocino County were not available for the last few years of the project but, from the figures recorded, it is believed that the trends in the two counties were similar.

The records kept by the different companies varied greatly in both detail and accuracy. The two large nurseries kept fairly complete records of the stock shipped to each company and also of costs. Most of the companies prepared maps of the planted areas but only a few kept detailed costs.

Very little experimental work was done. Occasional rows of check trees were staked out to serve as a basis for estimating survival by exposure, species, and class of stock. A few studies were undertaken to determine the effect of placing small strips of wood on the south side of the planting stock to reduce evaporation and temperatures, and others to determine the best time of the year for planting.

As previously stated, the total cost of the project was about $234,000. This is a considerable investment, and due credit should be given to those operators who contributed for the purpose of improving forest conditions on their cut-over lands. It should not be assumed, however, that this represents an exorbitant outlay for forest management. Costs of this nature may properly be included in the cost of lumber produced. So figured, the total cost is less than 5.5 cents per thousand on the 4.5 billion board feet of lumber produced by the cooperating companies during the period covered by the planting project—by no means a heavy burden on the industry.

This project was, however, one of the most ambitious commercial planting programs undertaken in this country. It was carried on for nearly a decade, involved a considerable expenditure of money, and received a great amount of publicity. It is important to determine, so far as available data permit, what was actually accomplished and the limitations and possibilities of this method of maintaining the productivity of redwood forest lands.

INVESTIGATION OF RESULTS

The virtual collapse of the redwood planting project in 1931 happened to coincide with the beginnings of a definite program of forest-management studies in the redwood region undertaken by the California Forest and Range Experiment Station. In view of this coincidence, the first place in the station's program was allotted to the study of the planting enterprise—its accomplishments and implications. This was done not because planting was considered the most desirable point of attack on the redwood-management problem, but simply as a matter of expediency. With the abandonment of private planting, the foresters who had directed the work were leaving to find employment elsewhere. It was apparent that, unless the study was undertaken at once, much information of wide interest and of value would be permanently lost.

The scope of the study was similarly governed largely by the conduct of the project. No attempt was made at an exhaustive study. That would only be possible where marked trees could be followed from the time of planting until they were fully established. In this case, not only had all planting been discontinued before the study was begun, but only a small number of check trees were available.

In spite of these limitations, however, it was possible to determine in some measure the success of the project and to obtain some important evidence on the possibilities of redwood planting as a commercial undertaking.

The specific purpose of the study was therefore to determine as accurately as possible the extent of the planting program actually put into effect, the number of trees, acreage, and cost; the methods used; and, where possible, the percent of survival as affected by a few of the most important factors, particularly class of stock, condition of site, and exposure. In this circular, these data are given as accurately as the accuracy of the sources of information permit. Some of the figures presented point to no definite conclusions and have even in some instances the appearance of contradiction. As a matter of record, however, their usefulness is not necessarily limited by the scope of this study.

FIELD STUDIES

As a result of preliminary investigations early in 1931, it was decided to make the best use of the time available by concentrating field studies on the planted areas of three companies that were apparently representative of the planting as a whole. Two of these companies, Union and Caspar, were located in Mendocino County, and the third, Pacific, in Humboldt County. Later, in connection with a study of the condition of cut-over land, more extensive sampling was made of the plantations of the other companies.

Two methods of sampling were thus used. Most of the data are from seventy-nine 0.1-acre plots, mechanically located for the planting study at 5-chain intervals on strips usually either 5 or 10 chains apart. Before the planting study had been completed, however, several planted areas were covered by the more intensive cut-over area sampling, and the plots so obtained were included. These were in the form of groups of four milacre quadrats mechanically located at 1-chain intervals on strips usually 5 or 10 chains apart.

On both types of plots complete notes were taken on topography, soil and vegetation, species planted, age and condition of all planted trees, and the history of the area—principally, when logged, last burned, and planted. Areas on which no samples were taken were examined extensively to obtain a rough check on the estimates of survival.

Several of the check plantations established by the cooperating companies at the time of planting or soon afterwards were examined and the survival was determined. On one plantation by the Pacific Lumber Co. of 1,800 staked and numbered trees, a more detailed study was made, including a comparison by exposures of the survival, height, and amount and kind of injury for the four different species used. Two burned-over plantations, one on Caspar lands, and the other on Albion lands, were also examined to determine what percentage of established seedlings would sprout following the killing of the tops by fire.

The tables and charts presented later are based on a total of about 10 planted acres, including the seventy-nine 0.1-acre plots and 1,925 milacre quadrats. This material is obviously only a meager sample

for the entire planted area of 26,423 acres. Even for the 14,289 acres planted by the three companies most intensively studied, it would amount to only 0.07 percent. The data are greatly strengthened, however, by the detailed examination of staked plantations, and the extensive examination of the planted areas not actually sampled.

It was impossible to determine survival accurately, since there was no record of the exact number of trees planted on each sample plot. An approximate figure was arrived at by comparing the average number of trees per acre planted on a given area with the number found through sampling. This method, giving a fair estimate of actual stocking from planted trees, serves as a rough check on survival.

STUDY OF COMPANY DATA

Information on the planting project was also obtained from foresters [4] and other company officials; from Lawrence Merriam, of Mason & Stevens, who had direct supervision of the entire planting project; and from W. R. Schofield of the Humboldt County Redwood Reforestation Association.

It was necessary to depend almost entirely on the company data for acreage and number of trees planted—by years, species, and class of stock—for costs, location of plantings, and methods used. Some figures on survival and the effects of certain factors were also obtained from this source. In a few instances, no accurate records were kept and the location of plantations as well as the survival figures were subject to some question. The total acreage planted is fairly accurate. Number of trees is undoubtedly a little high, since in a number of instances trees sent out from the nursery were not planted.

The company survival figures are based on comparison with the staked check rows established on most of the plantations. Unfortunately, the number of trees so staked was very small and in some cases the staking was done several months after planting. The percent of staked trees varied roughly from nearly 1 percent for the Caspar Lumber Co. to less than 0.01 percent for one or two of the largest companies.

CONDITIONS UNDER WHICH PLANTINGS WERE MADE

THE REDWOOD BELT

The redwood belt with its humid coastal climate, abundant moisture, equable temperature, and good soil is in general, despite a distinct drought period during the summer months, very favorable for forest planting. The rapidity with which vegetation invades newly logged areas, the steep slopes, and the large quantity of slash remaining even after the most severe burns, are factors which, though partially beneficial, add considerably to the difficulty of planting.

[4] Especial indebtedness is acknowledged to Gibbs, forester for Caspar Lumber Co.; Davis, forester for Union Lumber Co.; Wirt and Corbitt of Pacific Lumber Co.; Captain Elam and Stirwalt of Hammond & Little River Redwood Co.; Hood and Johnson of Albion Lumber Co.; Rutledge of Dolbeer-Carson Lumber Co.; and Bones of Northern Redwood Lumber Co.

The redwood belt is a distinct area with relatively definite characteristics and boundaries extending as a narrow strip, 5 to 25 miles wide, from the Chetco River of Oregon, 30 miles north of the California line, to the southern part of Monterey County. The narrowest portion of this belt is in northern Del Norte County and parts of Sonoma County; the widest, in the central part of Mendocino County. The principal part of the commercially available redwood area extends from northern Sonoma County to Smith River in Del Norte County; and all of the logging, with the exception of a few small outlying operations, has been concentrated in the general vicinity of two lumber centers—Fort Bragg, in Mendocino County, and Eureka, in Humboldt County—to which the present study is confined. The extent and location of the principal planted areas and adjoining cut-overs are shown in figures 1 and 2.

TOPOGRAPHY AND GEOLOGY

The topography is generally rough, with the short, steep, broken slopes characteristic of the geologically recent California Coast Range, but in spite of this ruggedness, the total relief is small for a mountainous country. Occasional peaks within the section reach an altitude of 4,000 to 4,500 feet. The principal streams drain to the northwest, with many intersecting secondary streams and gulches. Level flats and benches supporting pure redwood stands of almost unbelievable volume are found throughout most of the area, but they constitute only a small percent of the total. Most of the redwoods are found at elevations between 100 and 2,500 feet. There is probably no redwood type above 3,000 feet. Figures 3 and 4 show topography typical of many of the plantations.

The parent rock material of the section is largely massive marine sandstone of the upper Mesozoic, with considerable shale and lesser amounts of Mesozoic limestone and Franciscan slates, cherts, limestones, and sandstones. Serpentine and schists are fairly common in some localities.

SOIL

The soil, which is generally favorable for planting, varies from a thin rocky loam on some of the steepest slopes, to a fine, deep sandy loam on the flats and benches. The most characteristic soil where the trees were planted is a moderately deep sandy loam containing a variable admixture of fine to coarse rocky material (mostly sandstone), with a clayey subsoil. In some parts of the section the clays are close to the surface and clay loams and sandy clay loams take the place of the more typical loams and sandy loams.

CLIMATE

The climate, although variable within the section, is in general very favorable for planting. For a short period during the summer there is little or no precipitation, but the heavy fogs occurring commonly during this rain-free period compensate in a great degree for the deficiency. These fogs are also largely responsible for the high mean relative humidity characteristic of the region, which at Eureka is 90 percent at 5 a. m. and 80 percent at 5 p. m. Further

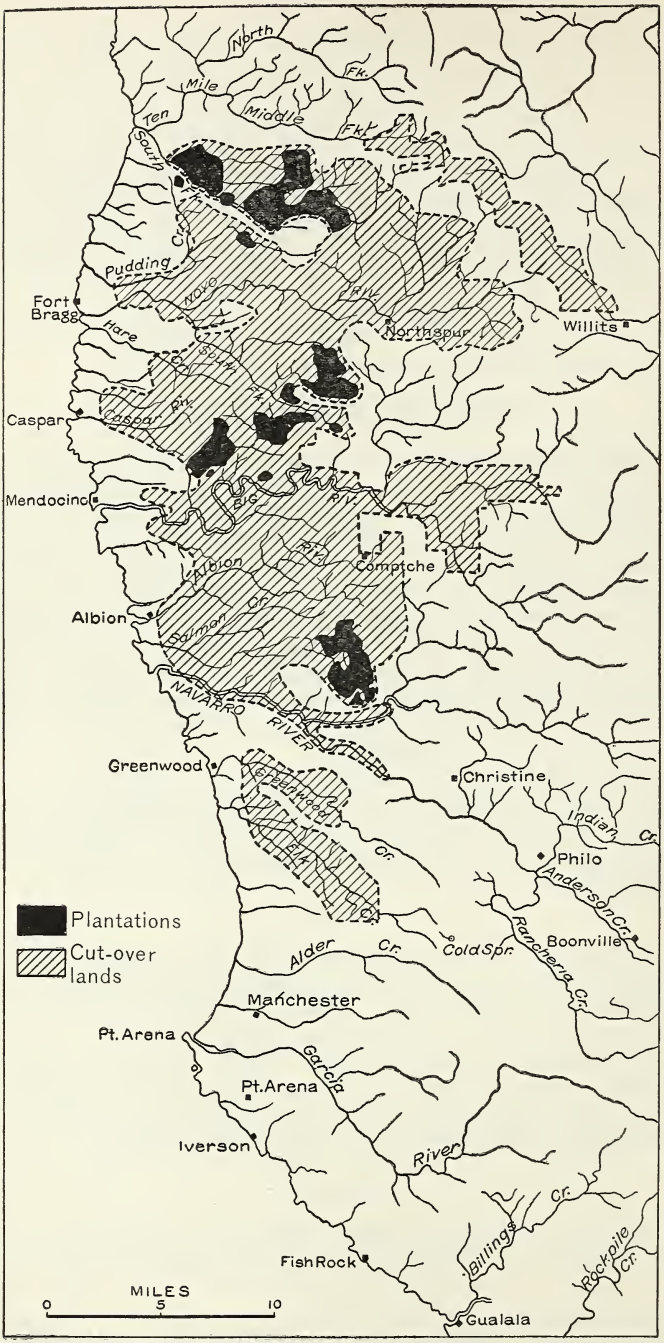

FIGURE 1.—Planted areas and redwood cut-over lands of Mendocino County.

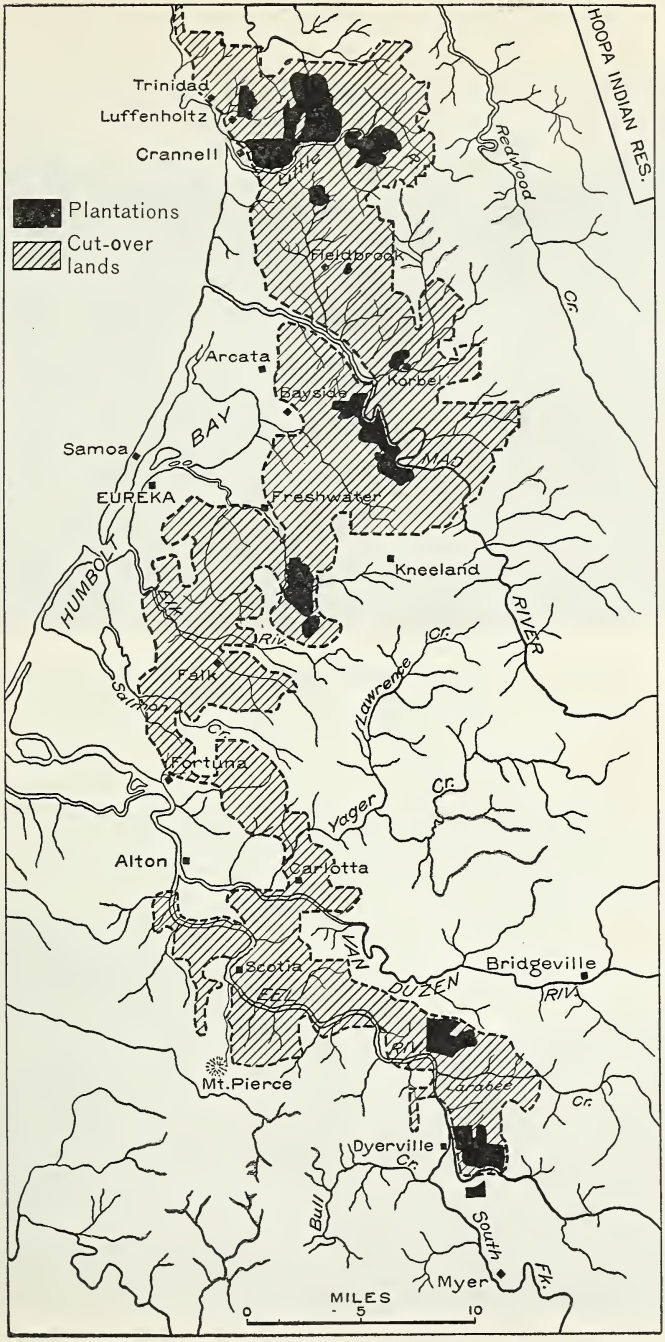

FIGURE 2.—Planted areas and redwood cut-over lands of Humboldt County.

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FIGURE 3.—Planted area on Pudding Creek, Mendocino County. The heavy cover on the upper slopes is mainly blueblossom.

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FIGURE 4.—More moderate planted slopes in Humboldt County. The planted trees are barely noticeable in comparison with the large redwood sprout clumps.

inland the relative humidity is lower, occasionally as low as 10 percent during the summer.

The average annual precipitation varies along the coast from 27 inches at Santa Cruz to more than 74 at Crescent City. Inland, near the center of the redwood belt, it varies from about 40 inches at Keene Summit, Scotia, and Rohnerville to 81 at Branscomb in northern Mendocino County. Practically all of the precipitation in the redwood forest falls as rain, although in the two counties studied the average annual snowfall at the higher elevations is 2 to 5 feet.

Equable temperatures are characteristic. The mean annual temperature varies between 50° and 60° F. with a difference between mean annual maximum and mean annual minimum of 10° or 15° at Eureka, Crescent City, and other coastal points, and 30° toward the eastern edge of the redwood type, as at Branscomb. The growing season, or frost-free period, varies from 6 to 11 months. Electrical storms are rare and usually accompanied by abundant rainfall. Although the winds are variable, southerly winds predominate during the winter and northwesterly winds during the summer. Occasional dry northeasterly winds during the hottest, driest part of the summer cause severe loss among planted trees and even considerable damage to well-established natural vegetation. The maximum wind velocity recorded at Eureka is 46 miles per hour.

ASSOCIATED VEGETATION

Virgin redwood lands, in the redwood transition life zone, support a very interesting flora, including a large number of species that are either limited to this locality or reach their optimum development there. The most important, both commercially and botanically, is, of course, the redwood (*Sequoia sempervirens* (Lamb.) Endl.). Redwood is found occasionally in practically pure stands on some of the best sites, usually on flats along streams or on the more gentle slopes below 1,000 feet elevation. On such sites trees over 300 or even 325 feet in height and between 10 and 15 feet in diameter are not uncommon. Usually, however, it is in mixture with other species, both conifer and broad-leaved, but always as the dominant. The most important of the associates is Douglas fir (*Pseudotsuga taxifolia* (Lamb.) Britt.). This species is well distributed throughout most of the redwood belt, admixed with redwood in different proportions and with other associates, and is by far the most abundant conifer aside from redwood on most of the eastern and southern parts of the area.

The other conifer associates of redwood are more limited in their distribution within the region. Lowland white fir (*Abies grandis* Lindl.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are the two commonest on the coast side of the area from northern Sonoma County north, and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) is an important coastal species from the Humboldt Bay area north. Port Orford cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.), western red cedar (*Thuja plicata* D. Don), California nutmeg (*Tumion californicum* (Torr.) Greene), and Pacific yew (*Taxus brevifolia* Nutt.), are less common but nevertheless characteristic elements in the flora in parts of the planting area.

Tanbark oak (*Lithocarpus densiflora* (Hook. and Arn.) Rehd.) and Pacific madrone (*Arbutus menziesii* Pursh) are the two most abundant and most generally distributed of the hardwood associates. Other less common associates found throughout most of the region include:

Golden chinquapin (*Castanopsis chrysophylla* (Hook.) A. DC.
Red alder (*Alnus oregona* Nutt.).
California laurel (*Umbellularia californica* (Hook. and Arn.) Nutt.).
Pacific wax-myrtle (*Myrica californica* Cham.).
Oregon white oak (*Quercus garryana* Dougl.).
Bigleaf maple (*Acer macrophyllum* Pursh).
Vine maple (*A. circinatum* Pursh).
Oregon ash (*Fraxinus oregona* Nutt.).
Cascara (*Rhamnus purshiana* DC.).
Willows (*Salix* spp.).

Among the most characteristic shrubs of the redwood type are:

Rhododendron californicum Hook.
Rubus parviflorus Nutt.
Vaccinium ovatum Pursh.
V. parvifolium Sm.
Gaultheria shallon Pursh.
Rhus diversiloba T. and G.
Ceanothus thyrsiflorus Eschsch.

Shade-loving ferns constitute an important part of the general ground cover on virgin land, particularly:

Polystichum munitum (Kaulf.) Presl.
Woodwardia chamissoi Brack.
Struthiopteris spicant (L.) Weis.
Adiantum pedatum L.
Dryopteris arguta (Kaulf.) Watt.

The flowering plants most conspicuous in the ground cover are:

Oxalis oregona Nutt.
Asarum caudatum Lindl.
Vancouveria parviflora Greene.

A large number of these trees, shrubs, and smaller plants of the virgin forest are sprouting species or reproduce readily from seed, and are consequently found in abundance on the cut-over lands within a year after logging. They provide a ground cover that protects the soil from erosion, as well as from drying out, and reduces ground temperatures. At the same time these plants are often so abundant that they interfere seriously with the planting work and compete with the planted trees for available soil moisture and space. This is particularly evident wherever planting is delayed for a year or more after logging.

Although the vegetation on the plantations includes most of the species found in the virgin forest, there is a marked change in the relative abundance of many of the species. This is due to the extreme alteration in site conditions caused by the increased exposure to sun and wind; the loss of surface humus and soil because of logging, slash fires, and erosion; and the marked increase in alkalinity of the surface soil. Some of the less tolerant or sprouting species such as Douglas fir, tanbark oak, madrone, western chinquapin, *Ceanothus thyrsiflorus*, *Rhododendron californicum*, *Vaccinium* spp., *Rhus diversiloba*, *Rubus* spp. *Gautheria shallon*, and *Polystichum munitum*, increase greatly in abundance at the expense of many of the nonsprouting, less aggressive, or more tolerant species. The greatest change in the flora of the planting sites, however, is brought about by the invasion, often in great abundance, of many species only rarely found, if at all, in the virgin forest. Most conspicuous among these plants are:

Epilobium spp.
Erechtites arguta DC.
E. prenanthoides (A. Rich.) DC.
Anaphalis margaritacea (L.) B. and H.
Gnaphalium spp.
Baccharis douglasii DC.
Sonchus oleraceus L.
Whipplea modesta Torr.
Hypochaeris glabra L.
H. radicata L.
Crepis capillaris (L.) Wallr.
Medicago hispida Gaertn.
Lolium spp.
Aira caryophyllea L.
Festuca megalura Nutt.

Some of the species most common to cut-over areas are shown in figures 5 and 6.

EFFECTS OF LOGGING METHODS AND SLASH DISPOSAL

Some knowledge of redwood logging methods is essential to an understanding of the planting problem, particularly of the extreme contrast between the virgin stands and newly logged areas ready

FIGURE 5.—The madrone, rhododendron, and fireweed (*Epilobium augustifolium*) shown here are species common to planted areas of the redwood section, as are those shown in figure 6.

for planting (figs. 7 and 8). It will also help to explain the strong preference of the operators for the clear-cut-and-plant method by indicating the extent of the change necessary to make possible selective logging and natural regeneration.

The logging methods used in the redwood region during the last 15 years have developed with the general improvement in machinery and particularly with the increase in the power and speed of donkey engines. Power logging up to 1916 or later was ground-lead logging. A form of economic selection was necessitated thereby because of the limitations of the logging equipment. As a result, seed trees survived on many of the areas and a number of fairly well-stocked

redwood second-growth stands from 20 to 70 years of age are to be found on some of the land so logged.

Between 1916 and 1920 high-lead logging came in, followed by skyline systems, particularly the slack skyline. At the same time the power and line speed of the machines were greatly increased and

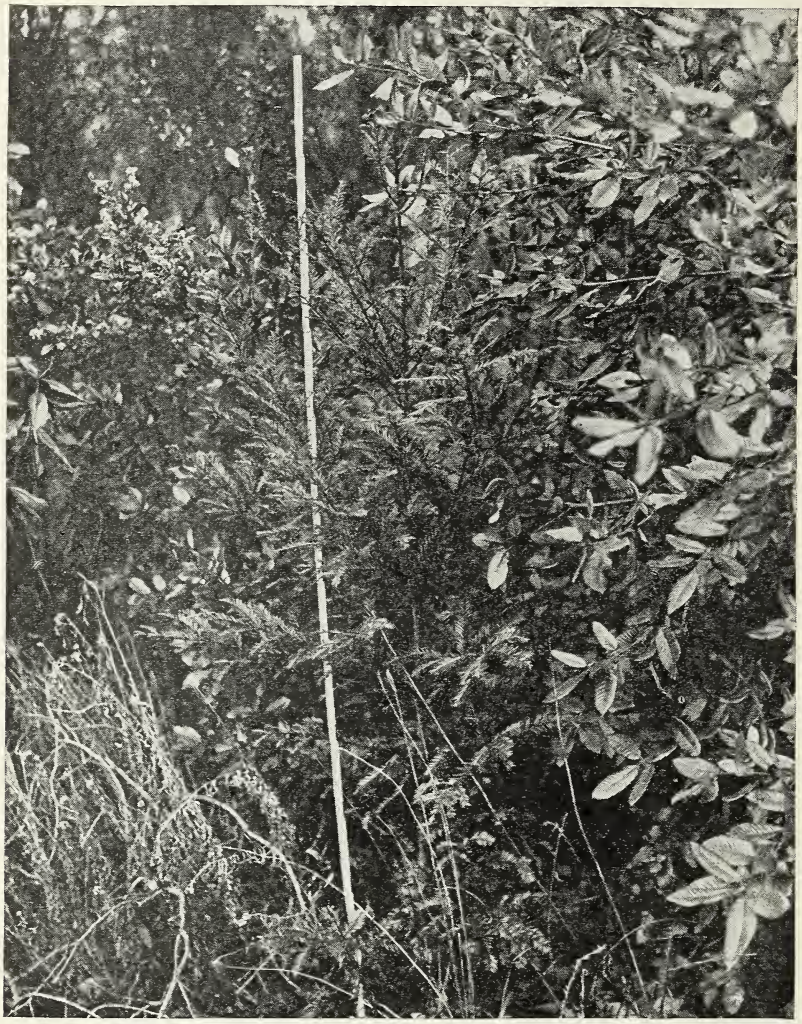

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FIGURE 6.—The planted redwood in the center is shaded by tan oak (right) and blueblossom (*Ceanothus thyrsiflorus*) (rear). At the left, everlasting is going to seed. These, like the species shown in figure 5, are characteristic associates of redwood in Mendocino County.

it became possible to transport the largest log directly from the stump to the landing at a high rate of speed and with little interference from the uncut part of the stand, which was pulled down without difficulty by the fast-moving lines and logs.

High-lead logging differs from ground-lead in that the cable is led through a block hung from a spar pole, which gives a lift to the front end of the log. It has been demonstrated that this method can be used without excessive damage, if proper care is taken and ground

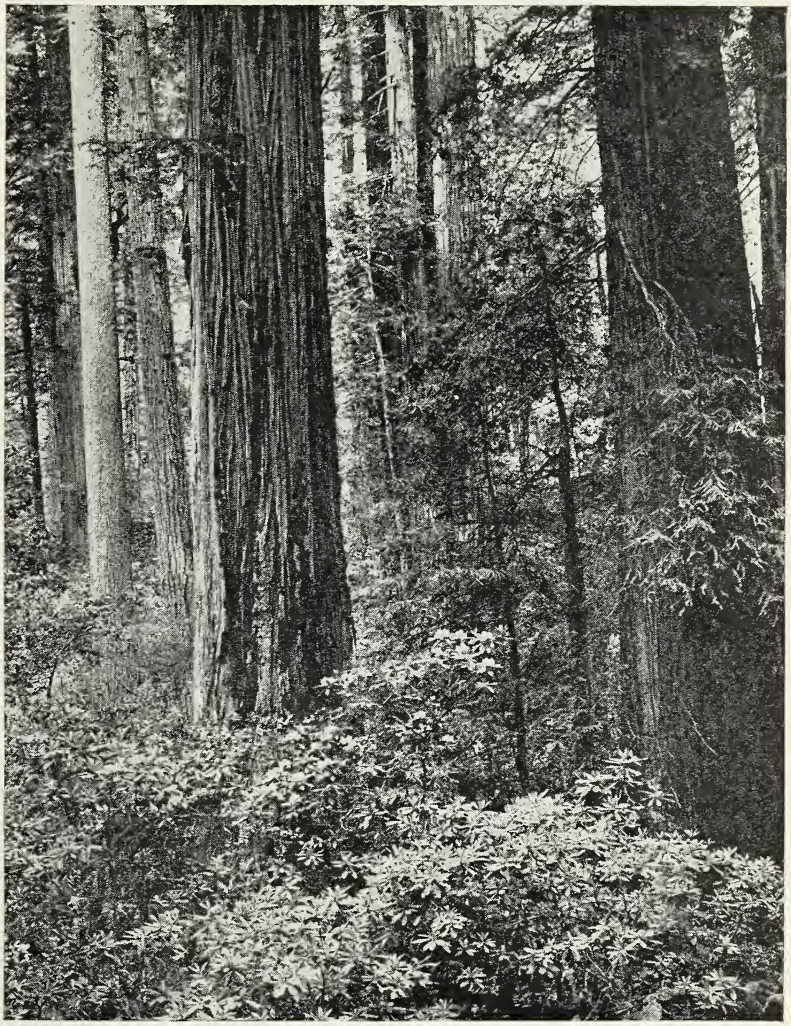

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FIGURE 7.—Virgin redwoods with associated species: Douglas fir, lowland white fir, and western hemlock; Redwood Creek, Humboldt County.

blocks, siwash trees,[5] and other means of controlling the course of the logs are employed. With the skyline system, in which the carriage rides an overhead cable direct to the spar tree, there is little if any opportunity to avoid obstacles by detouring the logs.

[5] Trees left to serve as bumpers to protect young growth from the logging lines.

The important feature of the slack-line system is a skyline that can be raised or lowered by means of a special drum. The method is destructive during actual yarding because the logs usually swing about when they are raised off the ground, thus damaging many of the trees that should be saved. Much of the destruction, however, occurs when the lines are moved from one yarding strip or "road" to the next. The standard procedure is to move the outer or tail end of the skyline to its new location, anchor it, and then pull the skyline into its new position simply by tightening the cable from the drum end. This usually sweeps down any tree that may have escaped pre-

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FIGURE 8.—Area which formerly supported an excellent stand of redwood. Logged 1931–32 with slack-line. Burned over early in 1933. Photographed in July 1933.

vious injury. The condition of a newly logged slack-line area is shown in figure 8. The slack line is one of the most destructive logging methods, and where it is used it is practically impossible to prevent severe damage to, if not complete destruction of, most of the forest cover.

Recently most of the companies have adopted the tractor as standard logging equipment, but in the heaviest stands of the northern part of the region the slack line is still commonly used.

It is practically impossible to leave enough seed trees to insure natural reproduction if slack-line yarding is practiced, and at best difficult and costly with high-lead yarding. Consequently, as long as these methods are used, planting will be necessary in order to maintain adequate stands. Tractor yarding, on the contrary, because of the small size and flexibility of these machines, is ideally adapted to selective logging and if generally employed, together with more careful use of fire, would largely eliminate the need for planting.

Slash disposal is also a serious problem in the redwood region. In addition to the numbers of small trees knocked down in the non-utilized part of the stand, large quantities of bark peeled from the redwood logs accumulate to form an enormous fire hazard. Two broadcast fires, one before yarding but after peeling, and one after yarding is completed, were the means normally taken to reduce this hazard. These severe fires, together with the damage during yarding, have on many areas resulted in the destruction of practically all surface vegetation and humus and completed the change from one of the most luxurious of forest types to bare, exposed slopes from which in many cases the best surface soil is lost through erosion. It is this extreme site deterioration which is the greatest hindrance to any form of natural or artificial reforestation.

The fact that the abundant sprouting species and very favorable growing conditions of the section bring about a rapid partial recovery and early restore a green protective cover, is deceptive. Soil values have been lost; sprout growth alone offers no hope of a well-stocked stand; and the destruction of seed trees results in an irreparable loss. The very presence of the protective cover may well be a hindrance to any future establishment of either planted or natural seedlings. It was found that this plant cover becomes so dense that very little reproduction is established later than 5 years after logging and the survival of planted stock is correspondingly low on the older cut-over areas.

Because redwood is relatively fire-resistant, many of the larger pieces of slash remain in spite of the severe slash fires. Where these are not too abundant, the net effect is beneficial because of the protection afforded to seedlings from sun, wind, and the trampling of stock. Where concentrated, however, in the bottom of draws and in the vicinity of landings, this slash seriously interferes with the planting.

CONDUCT OF PLANTING

SELECTION AND PREPARATION OF AREAS

It was found, early in the life of the planting project, that it was not only much easier to plant newly logged areas than older operations where other vegetation already formed a cover, but also that the survival and growth were much better on the newly logged land. Accordingly, the original plan, to include older cut-over areas and gradually to restock all lands on which reproduction was not becoming established naturally, was completely abandoned after the first few years. As interest in the project waned, few of the companies planted currently all of the newly logged areas.

The only selection of newly logged areas exercised was the setting aside of land to be used permanently for grazing or other nonforest use, and the avoidance, because of difficulty of planting, of some of the steepest slopes, as well as slash-filled gulches. No attempt was made to classify the land by sites or to restrict the planting to certain sites. A rough field selection for the planting of certain species was made, however. Sitka spruce, for example, was usually planted on the better sites and Douglas fir on the poorer.

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Little was done toward preparation for planting, except additional burning if the logging fires had not made as clean a burn as was considered desirable by those in charge of the planting. It was also the general policy to clean out fire trails around prospective plantations, so that they could be more easily protected from fires started on adjoining land.

PLANTING STOCK

SPECIES

Redwood, naturally, was selected as the principal species for planting. There were several economic reasons for this as well as the cultural advantage in using a native species with so many known favorable characteristics. The entire production and selling organization of the redwood industry is based on this special-use wood and, in order to interest the lumbermen in sustained operation, redwood would have to be maintained as the principal timber species. It was also recognized that redwood planting would be of more value for publicity purposes than other species because of the wide interest in the conservation of the redwood forest type. Other advantages of redwood include a high yield capacity, an adequate local seed supply obtainable at reasonable cost, immunity from tree-killing species of insects and fungi, and ability to recover from fire, rodent, and other injury through its sprouting habit.

Although the advisability of planting redwood was unquestioned, there was a difference of opinion as to the proportion that should be used. Some believed that redwood should make up only a moderate proportion of the total; others favored the use of redwood almost exclusively. The typical redwood virgin stand is a mixed type with redwood constituting from about 20 to as high as 95 percent of the total. Silviculturally, it is considered best to continue mixed stands in preference to pure stands, and some foresters, counting on the redwood sprouts to insure a fair proportion of this species in the final stand, favored planting only a small percent of redwood.[6] Also, it was considered that rapid-growing, limby second-growth redwood would not compare favorably with the virgin timber in durability or most other qualities and might even be less valuable than some of its associates.

In spite of these arguments in favor of using a high proportion of other species, however, the general popularity of redwood appears to have had a decisive influence, and redwood was selected as the principal species to be planted. The percent varied in the different plantings and from year to year, but the general average for the entire project was close to 80 percent.

The other species used in quantity were Douglas fir, which made up 10 percent of the total, Sitka spruce, 6.5 percent, and Port Orford cedar, 3 percent. California laurel and nutmeg were also used, but the amount was almost negligible, less than 0.4 percent of the total planting. A summary of the total number of trees planted from 1923 to 1927, by species and class of stock, is given in table 2. Complete figures are not available for the period 1927 to 1931.

[6] SHOW, S. B. TIMBER GROWING AND LOGGING PRACTICE IN THE COAST REDWOOD REGION OF CALIFORNIA. Introduction by R. Y. Stuart. U. S. Dept. Agr. Tech. Bull. 283, 22 pp., illus. 1932.

TABLE 2.—*Extent of planting in Humboldt and Mendocino Counties by the cooperating companies, by species and class of stock, 1923–27*

Species and class of stock	Plantings by companies in Humboldt County							Plantings by companies in Mendocino County							Both counties	
	Pacific	Hammond	Little River	Northern Redwood	Dolbeer-Carson	All companies		Union	Mendocino	Glen Blair	Caspar	Albion	All companies			
Redwood:	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*Percent*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*1,000 trees*	*Percent*	*1,000 trees*	*Percent*
1-0	1,314	800	537	243	50	2,944	75	714	347	37	586	486	2,170	54	5,114	65
1-1	15	24	6	2	0	47	1	301	207	10	264	365	1,147	29	1,194	15
2-0	0	0	0	0	0	0	0	44	0	0	0	0	44	1	44	(1)
Total	1,329	824	543	245	50	2,991	76	1,059	554	47	850	851	3,361	84	6,352	80
Douglas fir:																
2-0	125	25	42	8	0	200	5	66	40	0	3	46	155	4	355	5
1-0	64	99	29	25	0	217	6	36	0	0	0	0	36	1	253	3
1-1	13	0	0	0	0	13	(1)	119	23	0	0	0	142	4	155	2
2-1	0	0	0	0	0	0	0	24	0	0	0	0	24	(1)	24	(1)
Total	202	124	71	33	0	430	11	245	63	0	3	46	357	9	787	10
Port Orford cedar:																
1-0 2-0	56	47	39	14	0	156	4	55	0	0	5	0	60	2	216	3
1-1 2-1	3	3	4	0	0	10	(1)	17	1	0	0	0	18	(1)	28	(1)
Total	59	50	43	14	0	166	4	72	1	0	5	0	78	2	244	3
Sitka spruce:																
2-0 3-0	28	116	159	24	0	327	8	86	0	0	9	0	95	2	422	5
2-1	0	11	7	0	0	18	1	68	1	0	3	0	72	2	90	1
Total	28	127	166	24	0	345	9	154	1	0	12	0	167	4	512	6
Other species	0	0	0	0	0	0	0	6	10	0	9	1	26	1	26	(1)
All species	1,618	1,125	823	316	50	3,932	100	1,536	629	47	879	898	3,989	100	7,921	100

[1] Less than 1 percent.

Douglas fir, the least tolerant of all the species, was planted principally on the drier, more exposed ridges and southerly exposures. It was preferred to other species for these poorer sites because of its hardiness as well as for its rapid growth rate, wide natural range, and the proved value of its wood even from fast-growing second-growth trees.

Sitka spruce was used principally on the better sites where moisture was plentiful throughout the year, about two-thirds of the planting being in Humboldt County. It was included because of its high-yield capacity and the value of its wood—even of second growth—for a variety of uses.

Port Orford cedar was favored also because of the high value of its wood. This species was planted mostly on the better sites of Humboldt County, and to some extent in Mendocino County.

The advisability of using Sitka spruce and Port Orford cedar in Mendocino County, south of their natural range, was seriously questioned, except for experimental purposes.

CLASS OF STOCK

Several different classes of stock were planted, but 1–0 constituted nearly 70 percent of the total. The more costly 1–1 stock, making up 17 percent, was second in importance. The other classes—2–0, 3–0, and 2–1—were used in small quantities. The total planting in the first 4 years of record (1923–27), grouped according to species and class of stock, and the percentage of the total represented by each class, are given in table 3. Figures for the entire project were not available, but the percentages for these years are believed to be representative of the complete project.

TABLE 3.—*Trees planted, by species and class of stock, 1923–27*

Class of stock	Redwood		Douglas fir		Port Orford cedar		Sitka spruce		All species	
	1,000 trees	*Percent*	*1,000 trees*	*Percent*	*1,000 trees*	*Percent*	*1,000 trees*	*Percent*	*1,000 trees*	*Percent*
1–0	5,114	64.6	253	3.2	163	2.1	-------	-------	5,530	70
1–1	1,194	15.1	155	2.0	20	.3	-------	-------	1,369	17
2–0	44	.5	355	4.5	53	.7	[1] 422	5.3	874	11
2–1	-------	-------	24	.3	8	.1	90	1.1	122	2
Other	-------	-------	-------	-------	-------	-------	-------	-------	26	(2)
Total	6,352	80.2	787	10.0	244	3.2	512	6.4	7,921	100

[1] Including 3–0.

[2] Less than 1 percent.

NURSERY PRACTICE

At the two large nurseries the seed was sown between November and April, and early in the following fall the seedlings were root-pruned in the beds to 4½ inches. This stock was then ready for planting at the end of the first growing season in November or December. Redwood 1–0 stock produced in this way had tops of 3 to 8 inches and, as a result of the pruning, a bushy root system of about the same length with a fair number of fine lateral rootlets. At Scotia, only stock with tops more than 4 inches in height was selected for field planting, but at Fort Bragg seedlings with tops as short as 3 inches were used.

The tops of the redwood 1–1 stock ranged from 4 to 26 inches in height but the larger tops were cut back before planting to 8 or 10 inches. The roots, which grew to 18 inches, were cut back to 8 inches.

Douglas fir, Port Orford cedar, and Sitka spruce 1–1 and 2–0 stock had tops of 3 to 14 inches, averaging 8 to 10 inches. The roots of the transplanted stock were only a little longer than the tops, but the 2–0 stock had much longer roots—even to 3 feet in length.

As has been seen, practically all of the redwood used for field planting was either 1–0 or 1–1 stock. Some difference of opinion existed with regard to the comparative value of these two classes. In Mendocino County only 64.6 percent of all the redwoods planted were 1–0, whereas in Humboldt County 98.4 percent were 1–0 stock. Most persons connected with the planting work in Mendocino County believed that the additional cost of the 1–1 stock was more than repaid by the better survival and higher growth rate during the first few years after planting. This belief was supported by the data on survival for Mendocino County. The foresters of the Pacific Lumber Co., however, believed that there was little, if any, advantage in the 1–1 stock for use in Humboldt County and the available experimental evidence presented later supports their position.

One reason for this apparent inconsistency may be the difference in the handling of stock at the two nurseries. Satisfactory 1–0 stock must have short, bushy root systems, making it necessary to root-prune in the seedbed. The sandy soil at Fort Bragg, where Mendocino County stock was raised, failed to hold the roots firmly, so that the operator inevitably tore the roots and loosened the plants in pruning them. This set the seedlings back so severely that many of them failed to recover fully by winter. At Scotia, where the soil was heavy, the plants were only slightly disturbed by pruning, and healthy, stocky plants were available by planting time.

PLANTING SEASON

No planting was done before November 15 because the nursery stock had usually not completed its growth before that time, and in some years planting conditions were not favorable until as late as December 15 because of insufficient rain. As a result of studies by the Union Lumber Co., it was believed that trees set out after March 1 had less chance to survive than trees planted during December, January, and February. The reason advanced was that trees planted late in the spring did not become well established before the summer drought began.

No other investigations were made as to the best time for planting. Actually, there was little latitude except such as was provided by the weather. The time of first planting could be advanced somewhat if there was an abundance of early rains, but even this latitude was small, as too early field planting would shorten unduly the growing season in the nursery. The date of last planting could be safely extended only if there were some certainty of a late spring.

The time for planting was thus pretty well standardized between November 15 and February 15. During this period the only climatic danger was from frost, which might injure the plants directly or indirectly in the heaving of frozen soil. Very little loss actually resulted from freezing, although the tops often turned a reddish brown apparently from low temperatures.

PLANTING METHODS

Planting methods were in general similar to the usual Forest Service practice. At the nurseries the planting stock was adequately packed in moss with a protective paper and burlap cover to prevent drying out. The bundles, which contained from 1,000 to 5,000 trees each, were usually shipped to the planting sites by logging railroad or by car, or in some cases where no other transportation was available, packed in on the backs of donkeys from the end of the railroad. Most of the trees were in good condition when received by the planting foreman, who heeled them in immediately for later distribution as needed.

The field crews of 8 to 12 planters under one foreman carried their trees packed in moist moss in small canvas planting bags slung over

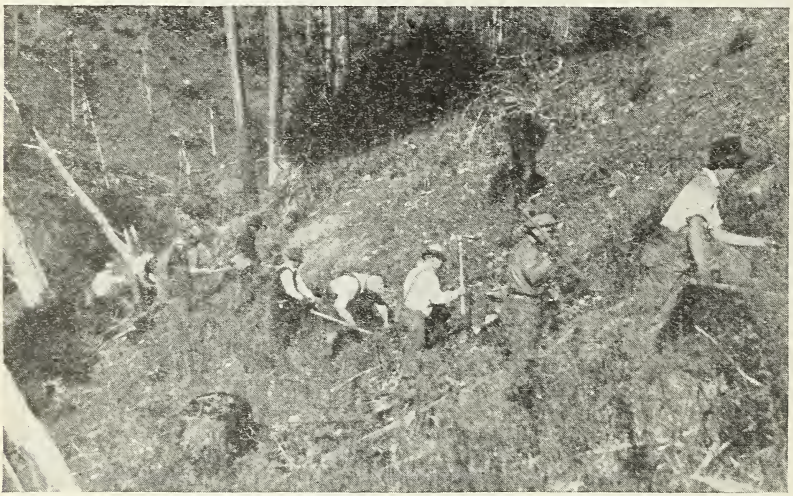

FIGURE 9.—Planting crew at work on slope. Photo by courtesy Pacific Lumber Co.

the shoulder. Some loss was caused here by lack of care in keeping the roots well protected with the moss. The planters usually worked up and down the slopes at right angles to the contours (fig. 9), but in some cases the planting direction paralleled the contours.

Two methods of planting were used, the slit method and the so-called one-man side-hole method. In both cases each planter worked as a unit, making the slit or hole with a small planting mattock, placing the tree in the slit or at the upper side of the hole, and packing in the dirt with the heel or the mattock. The Little River Redwood Co. used a narrow planting spade instead of the mattock. The principal difference between companies was that in some cases the soil was stirred up for a foot or more about the hole or slit, but in most of the planting there was no such preparation.

The spacing varied from 6 by 6 to 12 by 12 feet, averaging close to 8 by 8. Although this spacing should have resulted in a total of 680 trees per acre, the average actually was 480 per acre, since no planting was done within 8 feet of redwood stumps, most of which produced large clumps of sprouts within a short time after logging.

On some plantings, pieces of slash were placed on the south side of the newly planted trees to reduce evaporation and to protect the young stems from high temperatures. This practice undoubtedly paid good dividends except where fire weeds or other vegetation came in quickly enough to afford adequate protection. On one planting, most of the trees were planted on the north side of pieces of large slash with no attempt at uniform spacing. When this area was later grazed quite heavily, only the planted trees having this protection were able to survive the trampling and browsing.

Local labor was used in all of the planting projects but the supervision in most cases was supplied by technically trained foresters. It is believed that in some cases too much stress was laid on the rate of planting. In one instance where the standard planting rate was set at 800 trees per day, some of the men admitted that they threw away trees because they were not able to plant at the required rate. In another case entire bundles of trees were thrown away because the planting crews were too small to handle the number of trees sent to the planting sites by a company official.

The planting as a whole, however, was well handled and most of those in direct charge of the planting deserve commendation for the results obtained. This is particularly true in view of the natural difficulties of planting in rugged country, the lack of adequate experimentation, and the pressure from above to plant a large acreage at the lowest possible cost.

PLANTING COSTS

Planting costs for Humboldt County were decidedly lower than those for Mendocino County (table 4), averaging 71 to 74 percent. The Mendocino County operation included more overhead and supervision, more careful planting (particularly better preparation of planting holes), and more experimental work on time of planting, shading, and rodent control. It is believed that the better average survival of the Mendocino plantations, 41 percent compared with 32 percent for Humboldt County,[7] is at least partly the result of this greater care taken with the planting in Mendocino.

TABLE 4.—*Computed planting costs,*[1] *including cost of stock, in the redwood region, by county and lumber company*

County and lumber company	Total cost	Cost per acre	Cost per 1,000 trees	County and lumber company	Total cost	Cost per acre	Cost per 1,000 trees
Humboldt:				Mendocino:			
Pacific	$48,277	$8.30	$13.80	Union	$56,702	$11.01	$22.20
Little River Redwood	19,467	5.90	15.10	Mendocino	16,993	10.20	21.30
Hammond	20,587	7.29	18.40	Glen Blair	1,020	10.20	21.70
Northern Redwood	15,030	7.52	19.70	Caspar	34,680	10.43	21.80
Dolbeer-Carson	3,956	9.89	26.40	Albion	17,241	9.35	18.70
Total or average	107,317	7.48	15.80	Total or average	126,636	10.48	21.50
				Both counties	233,953	8.85	18.40

[1] Based on average costs for years 1924 to 1927 with complete cost data from Caspar and Dolbeer-Carson Lumber Cos.

[7] Estimated average survival. See table 7, p. 25.

Complete costs of the last 4 years of the planting period were not available for all companies. Those in table 4 are computed from 1923–27 costs and records of two of the companies for the full period. They comprise all items involved in the planting including planting stock, supervision, planting labor, preparatory work, fire protection, and experimental studies. The error introduced by the computation is small and can have little effect on the totals. Complete costs for 1923–31 from the Caspar and Dolbeer-Carson Lumber Cos. show no great difference between the first and the last 4-year periods. Detailed per-acre costs for the Caspar and Mendocino Lumber Cos. for 1929–30 (table 5) reach totals not inconsistent with the Mendocino County average in table 4.

TABLE 5.—*Sample planting costs 1929–30*

Caspar Lumber Co.		Mendocino Lumber Co.	
Item	Cost per acre	Item	Cost per acre
Planting labor	$4.86	General labor	$4.20
Supervision	.48	Planting stock	3.00
Surveying and staking	.11	Overhead and supervision	1.42
		Mapping	.18
Subtotal	5.45	Fire protection	.27
Cookhouse loss and pump man (extra cost)	.54	Hauling	.12
		Preparing land	.12
Total cost less stock	5.99	Cattle driving	.05
Stock 543 1–1 redwood, at $10 per M	5.43	Rodent control	.02
		Shading (experimental)	.57
Total	[1] 11.42	Total	9.95

[1] Cost per thousand trees, $21; cost per tree, $0.021.

The prices charged the cooperating companies for planting stock in two of the earlier years are shown in table 6.

TABLE 6.—*Cost per thousand of planting stock furnished by the Fort Bragg and Scotia nurseries, 1925 and 1926* [1]

Tree species and class of stock	1925		1926	
	Fort Bragg	Scotia	Fort Bragg	Scotia
Redwood:				
1–0	$7.00	$9.65	$7.00	$7.40
1–1	10.00	9.65	10.00	7.40
Douglas fir: 2–0	7.50		7.50	
Port Orford cedar: 2–0	10.00		10.00	

[1] Fort Bragg stock was 88–90 percent redwood of which 71 percent was 1–0; Scotia stock was 78–82 percent redwood, of which 95–98 was 1–0. The figures are taken from an unpublished report on redwood nursery practice by L. C. Merriam.

RESULTS OF PLANTING

As already explained, the results from a study of this kind cannot be given with the same completeness as those for the usual experimental research project. Because of the importance of the project, however, the attempt was made to piece together all available information and draw what conclusions appeared justified. Where

statistical data were insufficient or lacking, considerable weight was given to information obtained from field examinations by the author in company with foresters who had directed the planting work.

Where possible the results for the two counties are shown separately. Distinct differences in the climate and vegetation and in the logging and slash-disposal methods, made this separation desirable. In Mendocino County, where stands are lighter, logging methods are less destructive and consequent site deterioration is less severe. The average quality of the planting was also higher in Mendocino County. The results have been summarized in the form of tables and charts to show the average survival of the planted stock by species and class of stock and also how this survival was affected by certain factors.

SURVIVAL AVERAGES

Table 7 shows average survival figures for all species by companies and counties, on the basis of company records and field sampling; and the author's estimates of survival based on adjustment of the company and sample-plot data following field examinations of the planted areas. Although some degree of arbitrary adjustment is involved, these figures are believed to be reasonably close and the best available.

TABLE 7.—*General survival estimates for redwood planted areas, 1931*

County and lumber company	Company figures on staked check trees	Survival on 79 0.1-acre plots	Survival on 1,925 milacre quadrats [1]	Adjusted estimate of survival [2]
Humboldt:	*Percent*	*Percent*	*Percent*	*Percent*
Pacific	38	29	21	30
Little River Redwood	55			45
Hammond	30			20
Northern Redwood	34			30
Dolbeer-Carson	54			50
Average (weighted)				32
Mendocino:				
Union	33	22		30
Mendocino	55			45
Glen Blair	77		46	60
Albion	50			45
Caspar	66	68	28	60
Average (weighted)				41
Average				36

[1] Principally of value for the Pacific plantations, on which nearly three-fourths of the quadrats were laid out.

[2] Author's estimate based on a consideration of all available data supplemented by field examinations of the planted areas.

It is noticeable that the adjusted estimate is lower in every case than the percent based on company figures. One reason for this is that the adjusted estimate is for the survival as of 1931, whereas the company figures were mostly taken in 1927 or 1928, not taking into account the loss of trees between 1927 and 1931. Another reason for discounting the company figures is that in some cases the check rows were established some months after the trees had been set out, allowing unduly high survival percentages wherever trees dying between

planting and the establishment of the check rows were not included with the total planted.

The 0.1-acre plots, totaling nearly 8 acres, give reasonably good sampling for the three holdings for which this method was used. It was recognized at the time that the Union Lumber Co. samples were below the average for that company, because some of their best areas were inaccessible; on the other hand, the Caspar sampling favored the better areas somewhat. The Pacific sampling is probably close to the average.

The data from the 1,412 milacre quadrats on the Pacific Lumber Co. areas, unlike the data from the Caspar and Glen Blair quadrats, were taken as much for the purpose of rounding out the planting study as for use on the cut-over area study. Consequently, they are fairly representative of the entire cut-over area and include samples from almost every year of planting. The survival of 21 percent agrees reasonably well with the 29-percent survival from the 0.1-acre plots. However, it was known that in running the milacre-quadrat strips a small area of unplanted land had been included, and for this reason the final estimate was raised to 30 percent. A small amount of check sampling done in 1932 agreed quite closely with the 1931 estimates, except that in the case of the Albion Lumber Co. the original estimates were evidently high. How much too high was not determined because the Comptche fire of 1931 burned over most of the Albion plantations, making an accurate check impossible.

SURVIVAL BY SPECIES AND CLASS OF STOCK

A rough comparison of survival of different species and classes of stock is presented in table 8, based on company figures from check rows staked at or near the time of planting and checked by the author's examination of experimental plantations. Because there was no record of the number of trees of each species planted on the sample strips, it was not possible to get anything but gross survival figures from the sample-plot data. The company figures are all high, for reasons previously given, but they serve the purpose of comparison.

TABLE 8.—*Comparison, according to company figures, of average survival in 1931 by species and class of stock, 1923–27 plantings*

Species and class of stock	Humboldt County	Mendocino County	Average for region
	Percent	*Percent*	*Percent*
Redwood 1–0	40	52	45
Redwood 1–1	47	66	65
Average	40	57	49
Douglas fir 1–1 and 2–0	34	42	37
Port Orford cedar	70	58	66
Sitka spruce	38	67	47
Average, all species	41	56	48

Of particular interest are the following points:

1. The 65-percent survival of 1–1 redwood for the region is equalled only by Port Orford cedar. For the region as a whole, 1–1 redwood appears to be definitely the most successful species and

class of stock, in view of the wide variation in Port Orford cedar between the two counties.

2. Port Orford cedar has by far the highest survival in Humboldt County. Its success there is evident even from a general field examination. In several cases it would have been impossible to identify

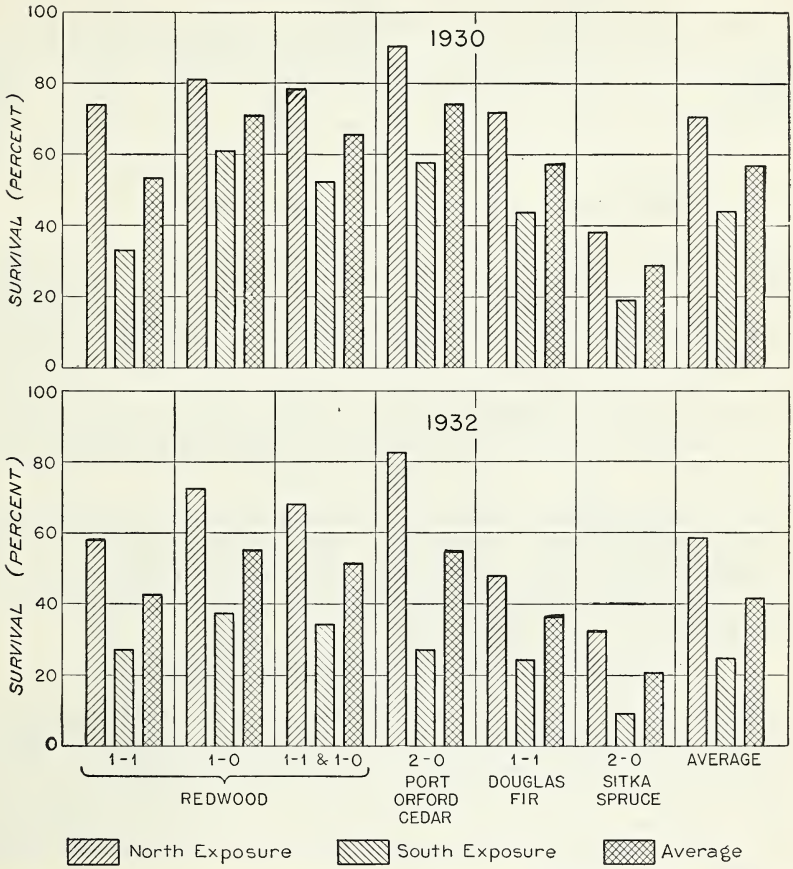

FIGURE 10.—Planted survival as related to exposure on experimental plantation of the Pacific Lumber Co. planted 1929–30.

a particular area as planted but for the unbroken rows of this species which could be followed even through heavy brush. Its favorable results in Mendocino County cannot be considered conclusive until more is known of its ability to acclimate itself so far south of its natural range.

3. Sitka spruce apparently excels Douglas fir, at least in Mendocino County, but this is at least partly due to the fact that the spruce was planted on the best sites and Douglas fir on the driest sites.

During the 1929–30 planting season, the Pacific Lumber Co. set out an experimental plantation of 1,800 trees to compare the survival of different species and classes of stock in the same location. Table 9 and figure 10 summarize the results of these plantings.

TABLE 9.—*Survival and rodent injury on Pacific Lumber Co. plantation of 1929–30* [1]

Species	Survival		Living trees injured by rodents	
	1930	1932	1930	1932
	Percent	*Percent*	*Percent*	*Percent*
Redwood 1–0	71.0	55.0	2.5	35.0
Redwood 1–1	53.5	42.5	0	27.0
Douglas fir	57.8	36.0	22.9	53.0
Port Orford cedar	74.5	54.8	26.5	61.0
Sitka spruce	28.5	20.2	2.6	27.0
Average	57.5	41.6	12.1	42.1

[1] Basis, 200 trees for redwood 1–1 and 400 for each of the other classes; total, 1,800 trees.

It is not to be expected that these results would be in close agreement with the 4-year survival figures in table 8, but it is interesting to note that the high survival of Port Orford cedar agrees with these data. Otherwise there is a marked divergence, probably largely explainable by the natural variability in conditions, as in the better survival of 1–0 over 1–1 redwood. This also accounts for the more favorable showing for Douglas fir over Sitka spruce, in that the part of the plantation occupied by both these species was a comparatively dry ridge that would be much more favorable for the fir than for the spruce.

The heavy increase in number of plants affected by rodent damage between 1930 and 1932 is noteworthy. Most of this damage is caused by wood rats, which are usually very abundant on redwood cut-over areas. It may be assumed that a large part of the mortality between 1930 and 1932 is due to this cause.

COMPARATIVE SURVIVAL OF 1–1 AND 1–0 REDWOOD

Because of the extensive use of both 1–1 and 1–0 redwood for planting, and the difference in the cost of producing the two classes of stock, an additional comparison of the results obtained is of interest. This is based on data from twenty-five 0.1-acre plots on Union Lumber Co. land and 30 from Caspar, together with data from the Pacific experimental plantation of 1.5 acres, one-third of which was redwood (table 10).

TABLE 10.—*Survival of redwood, 1–1 and 1–0 stock, as available from sample plot data*

County and lumber company	1–1 Redwood	1–0 Redwood
Mendocino:	*Percent*	*Percent*
Union	29.2	17.0
Caspar	72.4	35.6
Humboldt: Pacific plantation	42.5	55.0
Averages (weighted)	53.9	33.3

The superiority of the 1–1 stock in Mendocino County is marked, Caspar and Union plots together showing 90 percent better survival. In Humboldt County the experimental plantation data from 1,800

trees definitely favor the 1–0 stock. This alone, however, would not form a safe basis for general conclusions. A probable explanation of the difference in comparative survival of 1–0 and 1–1 stock between the two counties is that already given in discussing nursery practice.

HEIGHT AND CLASS OF STOCK

A comparison of height of the surviving trees in the 1–0 and 1–1 stock groups was based on records of 0.1-acre sample plots in Mendocino County (table 11), taking average heights at 1, 4, and 6 years

TABLE 11.—*Height of surviving planted redwood in relation to age and class of stock*

Age and class of stock	Average height	Basis, trees
1 year:	*Inches*	*Number*
1–0	5.5	31
1–1	7.0	482
4 years:		
1–0	9.0	76
1–1	14.5	84
6 years:		
1–0	23.5	84
1–1	39.0	215

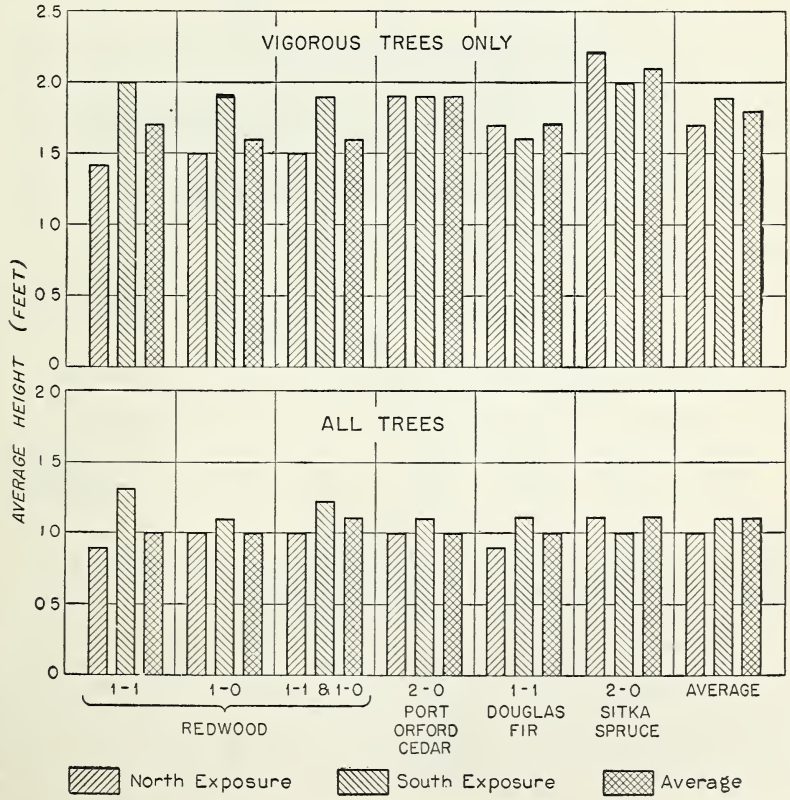

FIGURE 11.—Height growth in 1932 of species on the Humboldt County experimental plantation in 1929–30.

after planting. It is interesting to note (1) that the 1–1 stock grew at a much faster rate than the 1–0 stock; and (2) that, whereas the average annual height growth was 2.2 inches for 1–0 and 3.6 inches for 1–1 stock for the first 4 years after planting, the averages after 6 years were 4.0 and 6.5 inches, respectively. On exceptional sites a few trees planted in 1924–25 were over 100 inches in height in 1931, but most of the planted redwood grew at a much lower rate. This slow growth of the planted redwood was surprising in view of the known high annual increment of second-growth redwood stands. One reason for this may be severe deterioration of the site on logged and burned areas, particularly on unfavorable exposures.

The only comparative height-growth data available for Humboldt County, from the Pacific experimental plantation, are shown in figure 11.

HEIGHT GROWTH OF DIFFERENT SPECIES

Height data on species other than redwood are weak because only a few trees of the other species were found on the sample plots. They are summarized in table 12 and illustrated in figure 12.

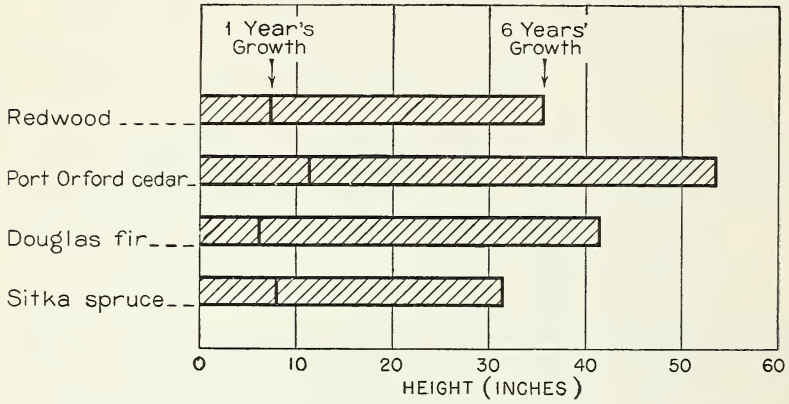

FIGURE 12.—Average heights of redwood and other species on sample plots.

TABLE 12.—*Average height of planted trees by species*

Species and age	Average height	Basis, trees	Species and age	Average height	Basis, trees
Redwood:	*Inches*	*Number*	Douglas fir:	*Inches*	*Number*
1 year	7	513	1 year	6	7
6 years	35	299	6 years	42	4
Port Orford cedar:			Sitka spruce:		
1 year	11	14	1 year	7½	5
6 years	54	44	6 years	32	43

Figures obtained from the Pacific Freshwater Plantation of 1,800 trees have already been shown in figure 11. A remarkable thing about this plantation is the uniformity of the average height of the different species. The maximum average variation between species (all trees) is only 0.1 foot. The fact that the average height of the living trees is slightly greater on the south exposure than on the

north exposure is also interesting, especially in view of the fact that the survival on the north exposure was more than twice as great as that on the south. This apparent inconsistency may be the result of greater mortality because of more critical temperature and moisture conditions on south slopes in the summer resulting in the survival of only the more vigorous trees, together with more favorable temperatures on south slopes during the rainy season, which would result in better growth in the surviving trees.

In spite of the weakness of the data, the comparative growth rates for the different species as shown agree fairly well with known performance in early years of growth. Port Orford cedar becomes established more readily than the other species and so would make good growth earlier than the other species. Douglas fir is relatively faster growing than the table indicates because much of the Douglas fir was planted on the poorest sites. On favorable sites young Douglas fir is known to grow at least as fast as any of the other conifers in the redwood region. One young Douglas fir was measured that had grown 9 feet in 2 years.

INFLUENCE OF VARIOUS FACTORS ON SURVIVAL

INTERVAL BETWEEN LOGGING AND PLANTING

The effect that length of time between logging and planting has on survival of planted trees was indicated by the analysis of the survival data on the 0.1-acre plots, results of which are shown in table 13 and figure 13. The data were divided to show the effect of the different intervals on both 1–0 and 1–1 redwood stock. This was done so that a higher percentage of one class of stock would not affect the results. The north and south exposures were about evenly represented in each interval class.

TABLE 13.—*Survival of planted redwood in relation to the interval between logging and planting*

Interval	Survival			Basis, plots	
	1–0 stock	1–1 stock	Average	1–0 stock	1–1 stock
	Percent	*Percent*	*Percent*	*Number*	*Number*
0–1 year	47	61	55	6	26
2–3 years	28	----------	28	7	0
4–5 years	24	----------	24	5	0
6 years or more	15	17	16	13	5

It is evident from these data that survival is definitely related to interval between logging and planting, and that best survival can be expected on areas planted within a year after logging, other factors being equal. The longer the interval the greater the density of competing vegetation is likely to be, and the more difficult it is to establish a stand. This is particularly true in the redwood region where a dense vegetation cover is often established within a very short time after logging. The consistency of the relationship shown in table 13 indicates that it is probably one of the most important of the factors studied.

EXPOSURE

It has been found in practically all planting studies that there is a definite relationship between survival and exposure, particularly for northerly and southerly exposures. This is to be expected because two of the factors that affect planted stock most directly, moisture and temperature, usually vary with exposure. Where moisture deficiency (either owing to lack of soil moisture or excessive evaporation) and high temperatures are limiting factors, it is natural that northerly exposures would be more favorable for newly planted stock than southerly exposures.

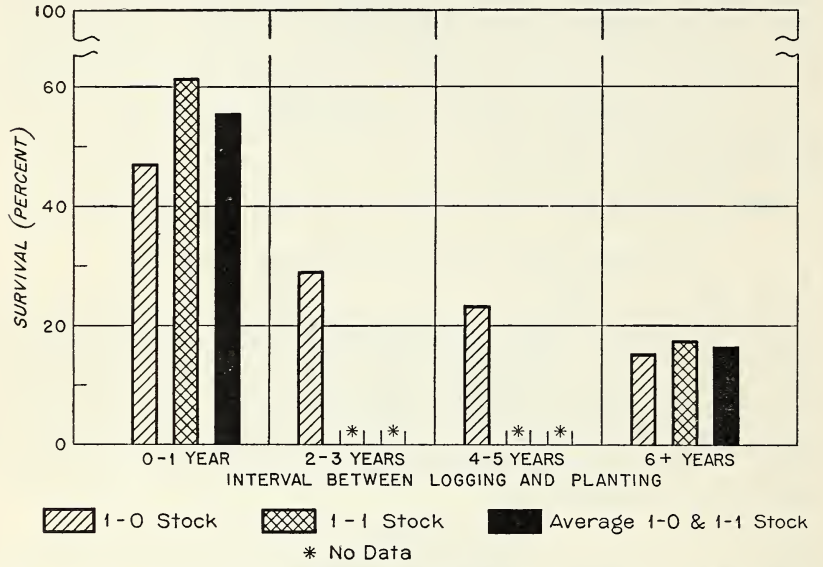

FIGURE 13.—The interval between logging and planting in relation to the survival of planted redwood trees.

The exposure of the 0.1-acre and the milacre plots was recorded in the field on the basis of eight exposures. In the office analysis these eight exposures were reduced to four by including all northeast or northwest plots under north and all southeast or southwest under south. This was done deliberately to provide a strong basis for comparing northerly with southerly exposures even though the east and west comparison was weakened by so doing. The data on survival taken by the lumber companies compared the four cardinal exposures on an equal basis. Table 14 shows the survival on the 0.1-acre sample plots and the Pacific experimental plantation.

Although there is a wide variation in survival among the plantings by the different companies because of differences in planting conditions and methods, it is evident that the north and east exposures show generally higher survival than south and west. The data on east and west exposures, however, are not very conclusive. The differences in favor of north exposures as compared to south are definite both for the individual companies and for the averages of all the companies.

TABLE 14.—*Survival of planted trees by exposures from one-tenth-acre plot data, supplemented by Pacific experimental data*

Exposure and company	Survival	Basis, plots
North:	*Percent*	*Number*
Union	32	14
Pacific	44	[1] 12.5
Caspar	68	12
Average or total	47	38.5
South:		
Union	12	10
Pacific	27	[1] 15.5
Caspar	46	11
Average or total	29	36.5
East:		
Union	13	2
Pacific	27	4
Caspar	70	5
Average or total	44	11
West:		
Union	12	3
Pacific	24	3
Caspar	44	2
Average or total	24	8
Average all plots (weighted)	35	
Basis		94

[1] Including Pacific experimental area of 1.5 acres equivalent to 7½ one-tenth-acre plots.

Results on the milacre quadrats are shown in table 15, where the average survival of each of the four cardinal exposures and for level sites, and the average of all exposures are summarized. The 0.1-acre plot data and company data are included for comparison. The milacre quadrats are not well enough distributed to allow comparison by companies.

TABLE 15.—*Comparison of survival data by exposures, from 0.1-acre plots, milacre quadrats, and company records*

Exposure	Survival on 0.1-acre plots	Milacre quadrats		Company data
		Survival	Basis, quadrats	
	Percent	*Percent*	*Number*	*Percent*
North	47	42	679	63
South	29	13	906	26
East	44	17	141	57
West	24	23	124	48
Level	0	13	75	
Total or average	35	24	1,925	44

The milacre quadrat figures agree with the 0.1-acre plot data in showing a high survival on the north exposure, 42 percent, and a lower survival on the south; they disagree in that the survival on the west is better than that on the east. This disagreement may be significant or may be due to weakness of the data, since only 141 quadrats were included for the east slope and 124 for the west, as compared to 679 and 906 for the north and south, respectively. One

reason for the low survival on the level areas is that they are more commonly used for grazing than are the slopes.

Survival on the basis of company data, also shown in table 15, substantiates the 0.1-acre plot data in that the best survival is on the north and east exposures, the poorest on the south and west. The difference between north exposures with a survival of 63 percent and the south with a survival of only 26 percent is particularly striking.

The comparison of the data from all sources (fig. 14) shows the highest survival to be on the north and the lowest on the south. East and west exposures are intermediate. Although neither has

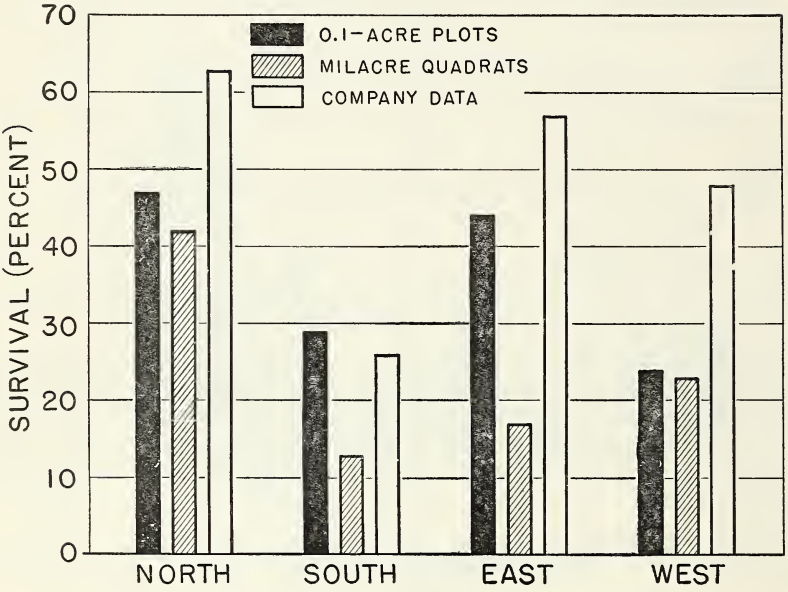

FIGURE 14.—Survival by exposures, comparison of data.

consistently better survival than the other, east exposures are apparently somewhat superior to west. It is possible that this inconsistency in east and west exposures is not owing to inadequate data but may be due to a natural variation in conditions found on the planted areas. Differences on the same exposures because of varying soil conditions, slope gradient, and particularly degree of exposure to beneficial fogs or dry northerly winds, may well be greater than the natural differences between the two exposures. That under some conditions west may be superior to east is supported by the results of recent studies of reproduction on redwood cut-over areas where the analysis of data from 15,660 milacre quadrats showed slightly better stocking of both conifers and hardwoods on west exposures than on either east or north exposures.

GRAZING

No definite data are available on the effect of grazing on the planted stock. It was observed, however, in the course of field

examinations that cattle caused serious damage in planted areas: and all foresters connected with the planting were unanimous in their belief that it was not practical to attempt to establish reproduction on areas being grazed.

There are several reasons for this. In the first place, the grazing and planting conflict in point of time. Cut-over land is suitable for grazing for only a few years after logging, unless reburned and seeded; and planted stock can be satisfactorily established only within a short time after logging. Where grazing is heavy, failure of the plantation is almost certain to result from trampling and browsing. Trampling is particularly severe on steep slopes. Here the cattle, if at all numerous, prefer to stand on the planting spots, which provide the only approximately level footing.

Another reason for the incompatibility of the two uses for cut-over land is that management that favors forage production is largely unfavorable for the establishment of reproduction. Cut-over lands are "developed" for grazing use by burning as cleanly as possible all remaining debris and by broadcasting grass seed. The fires are usually so severe that most of the humus is destroyed, and on the steep slopes much of the remaining topsoil is lost through erosion. Furthermore, the sod formed when the seeding operation is successful is likely to choke out the planted stock and prevent its establishment. It was found in a study of conditions on cut-over areas that grass was the type of vegetation least favorable for the establishment of natural seedlings. This conclusion was supported by the results of the Dolbeer-Carson planting which showed 14-percent lower survival on areas which had been seeded for grazing than on nonseeded areas even though cattle were excluded after planting.

The commercial planting experiment thus gave fairly strong evidence that to plant areas that are to be used for grazing is a waste of effort. It is apparent that a company intending to plant should decide definitely what areas are to be set aside for reforestation and should then prohibit all grazing and all preparations for grazing on such areas.

FIRE

LOSSES

Losses from fire on the plantations have been considerable, despite efforts made to protect them. Caspar, Union, Hammond, and Albion Lumber Cos. each have lost anywhere from 200 to 2,000 acres. It was reported that over 1,400 acres planted by the Pacific Lumber Co. burned over during 1932. The severest loss from a single fire was suffered by the Albion Co. during the Comptche fire in September 1931, when all but 50 of the 1,844 acres planted were burned over. It was estimated that about 90 percent of the Douglas fir and other nonsprouting species was killed in this fire, but only 10 to 20 percent of the redwood. As 80 percent of the plantation was redwood, the loss in actual number of trees killed was probably not as great as the loss in growth and form and in site deterioration.

To determine the effect of fire on planted redwood, three of the staked plantations on the Albion area (nos. 1, 2, and 2 D of the Flynn Creek plantations) were examined in May 1932. Plantation no. 2,

(fig. 15) was reexamined in October of that year to determine the additional mortality during the summer.

A three-man crew was used for the examinations and the status of the tree at each stake was recorded as missing, present but dead, top-

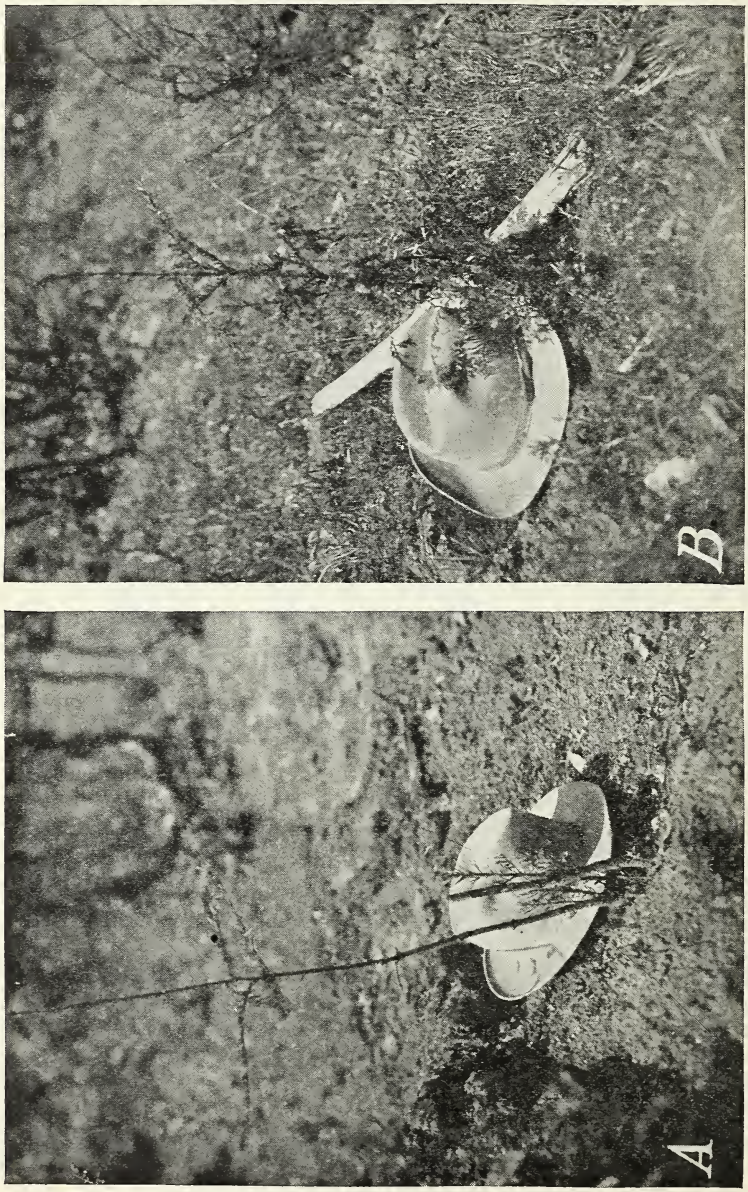

FIGURE 15.—Planted redwood top-killed by fire on Flynn Creek plantation no. 2: *A*, 36-inch redwood severely burned but sprouting. *B*, 30-inch redwood, foliage killed but not consumed, also sprouting from base.

killed and not sprouting, top-killed by fire but sprouting, and top green. The results, summarized in table 16, show that 88 percent of the top-killed trees survived by sprouting. As this burn was very

severe the figures of survival are probably conservative. Heavier loss would, however, occur on steep slopes where the combined effect of fire and erosion might destroy the sprouting ability of the small burl that forms on most redwood plants just below the ground level.

TABLE 16.—*Condition of planted redwood burned over in 1931, examined in May 1932*

Item	Plot no. 1		Plot no. 2		Plot no. 2D		All plots	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Top-killed, not sprouting	3	2	10	2	4	6	17	2
Top-killed, sprouting	41	32	76	14	13	20	130	18
Total	44	34	86	16	17	26	147	20
Top living [1]	--------	--------	37	7	17	26	54	7
Total survival	44	34	123	23	34	52	201	27
Trees missing	85	66	412	77	31	48	528	73
All stakes checked	129	100	535	100	65	100	729	100
Survivors top-killed	--------	100	--------	70	--------	50	--------	73
Top-killed, that sprouted	--------	93	--------	88	--------	76	--------	88

[1] Fire-injured or not.

Because the exact condition of each tree just before the fire was not known, it was assumed that if there was evidence of the tree's presence after the fire, it was living before the fire. On this basis, survival on the three plots was found to be only 27 percent. This figure is probably a little low, since wherever slash was concentrated or dry brush abundant even living trees might be entirely burned out.

An examination of a Caspar Co. area that was planted in 1924–25 and burned in September 1930, gave similar results, save that the survival of trees that were alive before the fire was in this case approximately 90 percent.

PREPARATORY FIRES

In addition to protection from fire after planting, which was inadequate on most of the planted areas, it is evident that more care was needed in the use of fire in preparation for planting. In many cases it may have been true that a single slash fire was needed to remove the enormous accumulation of debris that resulted from redwood logging as it was conducted on these areas. Subsequent fires for the purpose of making a clean burn were, however, and probably always are likely to be, entirely destructive. It was noted under the discussion of height growth that the growth of the planted redwood was even more disappointing than its survival. It is believed that this disappointing height growth and the poor survival as well were due in large measure to the site deterioration that resulted from the severe fires followed by heavy rain. This was particularly evident on the steep southerly exposures, where the destruction of all humus and much of the slash—which helped to conserve moisture and protect the seedlings from direct sun and drying winds—together with the loss of soil fertility, made reforestation practically impossible.

Although the evidence from these plantations leaves the question of how and when fire is to be used in preparing areas for planting

still unanswered and requiring future research for its satisfactory solution, it is at least clear that care must be taken in any burning operation to guard against the destruction of soil fertility. It is also apparent that a reasonable quantity of slash is undoubtedly beneficial even though it may slightly increase the cost of planting.

RODENTS

Wood rats are unquestionably one of the most harmful of the factors limiting the survival of planted trees. Table 9 has already shown that in the Pacific Co. experimental plantation of 1,800 trees, examined in 1932, 42 percent of all of the living trees bore evidence of rodent injury; and it is probable that a large part of the 58 percent that had died by 1932 were killed by rodents. A representative of the Bureau of Biological Survey, after spending some time on the study of rodent damage to planted trees in Mendocino County, reported [8] that 35 to 50 percent of the redwoods set out there were destroyed by rodents, principally wood rats. This estimate is undoubtedly high for many planted areas but it is true that rodents are generally one of the most important causes of mortality and in many instances the most important.

Fortunately rodent damage is usually not severe on newly logged land and that fact probably accounts in part for the much better survival where planting came soon after logging. It is evident that where a large rodent population is established, planting is likely to be largely unsuccessful. Unpublished data on the reports of attempts to establish reproduction in the brush fields of the California pine region indicate the similarity of the two regions in this regard.

COMPETITIVE VEGETATION

The effect of the competition of other vegetation on the survival of planted trees was difficult to determine because of the number of factors involved, and little progress was made toward a solution. The records from the 0.1-acre plots included presence, size, species, and location of vegetation close to planted trees, but it was not possible to show any relation between this vegetation and survival.[9]

SUMMARY AND CONCLUSIONS

Private efforts to reforest redwood cut-over lands in Humboldt and Mendocino Counties, Calif., between 1922 and 1932 resulted in the planting of some 12,700,000 trees on 26,400 acres at a cost of approximately $234,000. Redwood was the principal species used, with Douglas fir, Port Orford cedar, and Sitka spruce making up the remainder of the planting stock.

On sample plots survival averaged 36 percent for both counties—32 percent in Humboldt County and 41 percent in Mendocino County. Port Orford cedar and 2-year-old redwood transplants gave the best results. Survival on steep southerly exposures was particularly

[8] The Survey, mimeographed house organ of the Biological Survey, vol. 6, no. 4, Apr. 30, 1925.

[9] A report covering a more thorough study of the effect of vegetation on natural reproduction is now in preparation.

poor, amounting to complete failure in some cases. Height growth was generally disappointing. Although 6-year-old planted trees 9 feet in height were found, the average was barely 3 feet.

Length of time between logging and planting was found to be directly related to the success of a plantation. Planting within 1 year after logging resulted in more than twice the survival attained after a delay of 2 or more years. An important cause of failure in the latter cases was rodent injury, which on many of the plantations was probably the greatest single cause of failure. Other important causes of loss on both old and newly logged areas were weak stock, poor planting, poor site, drought, and injury from grazing and fires.

As a result of this study it is reasonable to conclude that fairly successful planting is possible in the redwood region at moderate cost if new-logged areas are planted promptly and due care is given to choice of stock. On steep southerly exposures and on old logged-over areas, however, more research, particularly in rodent control and the strip method of opening up vegetation with power equipment, should precede any extensive planting. Further study is also desirable as to the extent to which clear cutting and clean burning, which normally precede planting, result not only in the complete destruction of all advance growth but in severe site deterioration as well.

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